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РАН

НПП "ГИКОМ"

Low Frequency Gyrotrons for Fusion

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Outline

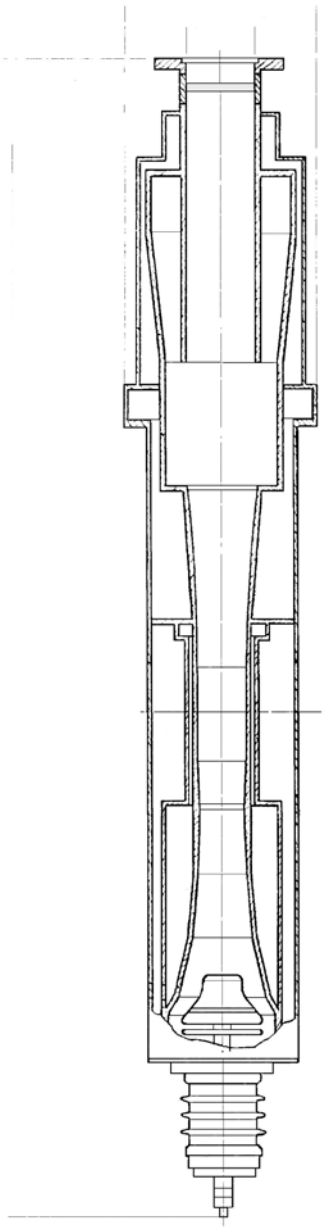
- · Introduction
- · Design Features
- · Cavity modes
- · Electron gun
- · Quasi-optical mode converter
- · Experiments
- Conclusion

Introduction

- For some experimental plasma set-ups powerful RF sources with frequency from 5 GHz up to 30 GHz are requested.
- The report presents the results of the low frequency powerful gyrotrons development in Russia. Test results for 5GHz/0.5 MW and 28GHz/0.5MW gyrotrons are presented.
- Several design versions of 5 GHz, 17.5 GHz and 28 GHz gyrotrons with output power 0.5-1 MW, its specific property details, special technical problems and test set-up are discussed.

DIFFERENCE of mm and cm Gyrotrons

	Problem	mm	cm
1	mode selection	+	–
2	cavity heat loading	+	–
3	electron beam	+ initial velocity spread	+ Non adiabatic effects
4	mode converter	+	+ +
5	collector	+	+ +
6	window	+	–



5GHz/500kW/1s Gyrotron

- Operating mode — $TE_{0,1}$
- Wavelength — 60 mm
- Electron energy — 70 keV
- Beam current — 25 A
- Pulse duration — 1 s
- Efficiency — 30 %
- Output power — 500 kW

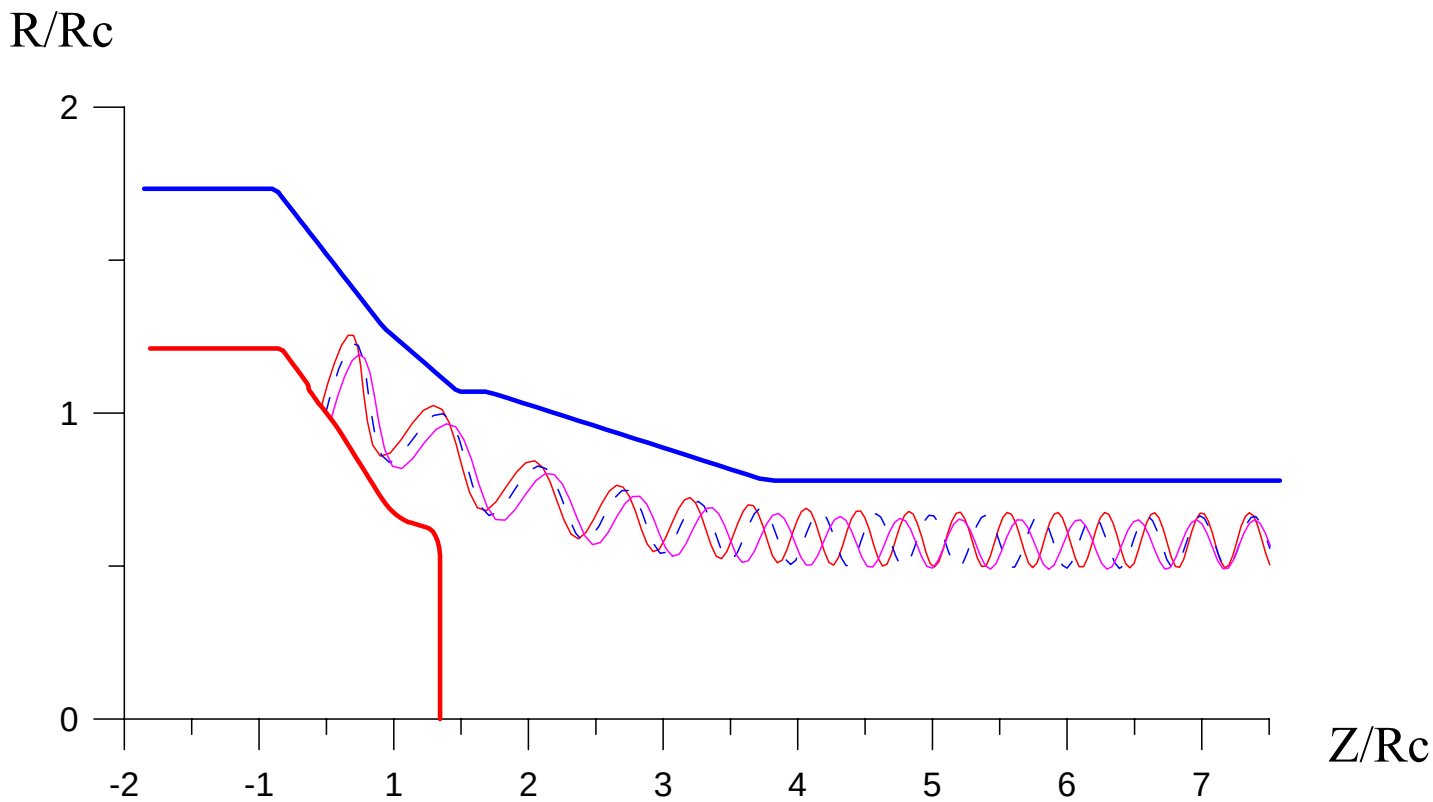
5GHz/500kW/1s Gyrotron

DIODE-TYPE MAGNETRON INJECTION GUN

Beam voltage	**70 kV**
Operating beam current	**25 A**
Cathode radius	**45 mm**
Beam radius at cavity	**25.6 mm**
Emitter current density	**2 A/cm^2**
Pitch-factor	**1.3**

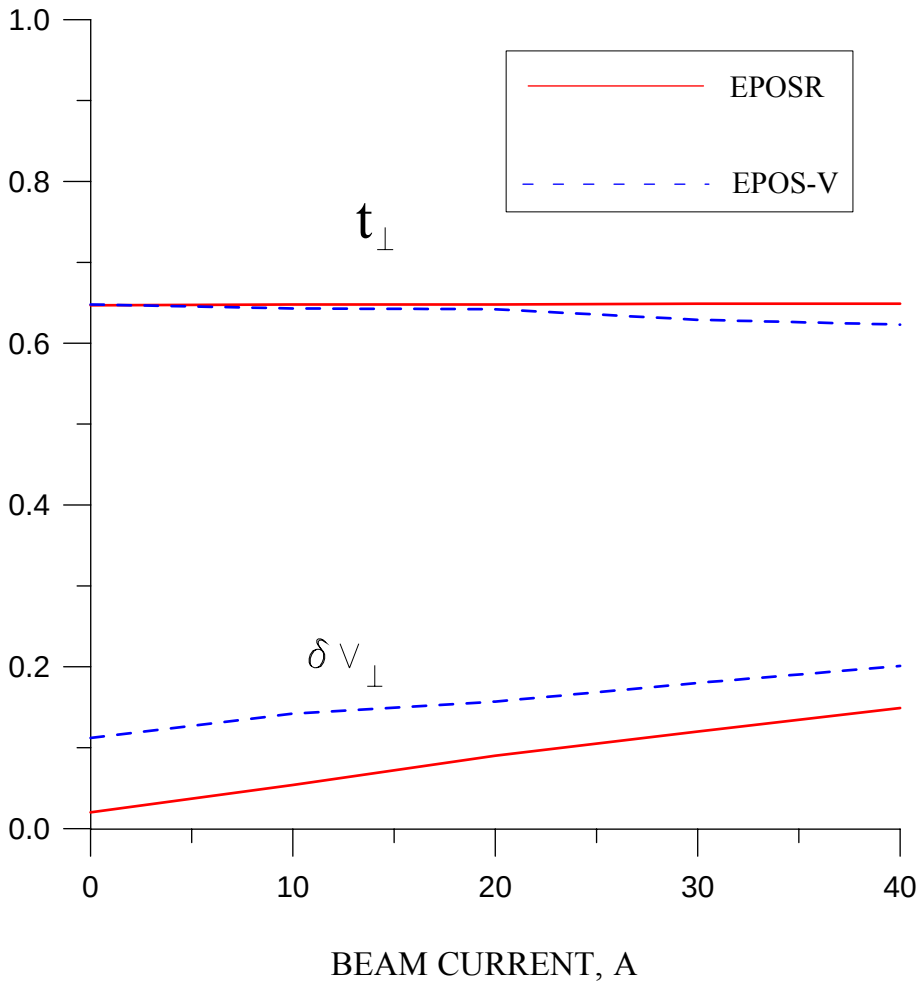
5GHz/500kW/1s Gyrotron

DIODE-TYPE MAGNETRON INJECTION GUN



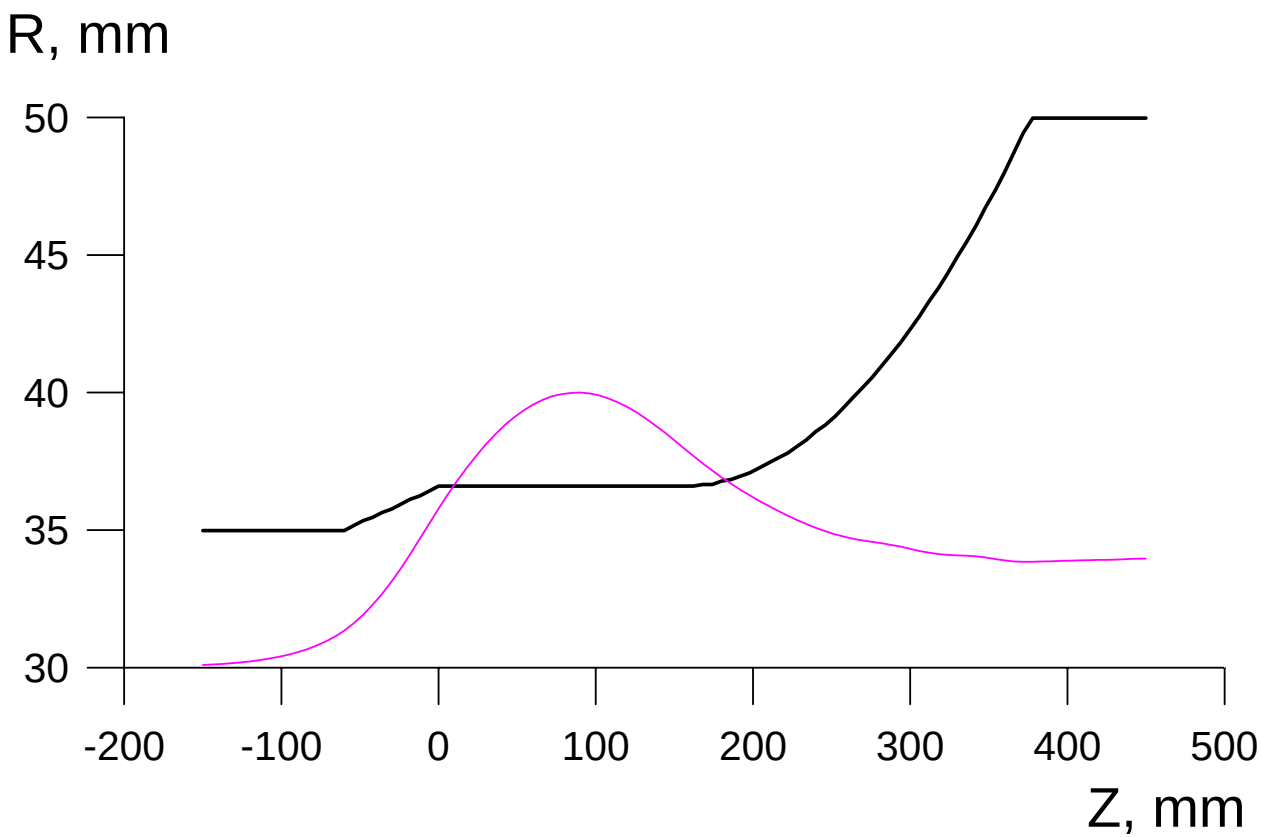
5GHz/500kW/1s Gyrotron

The velocity spread and average oscillatory energy vs. beam parameters



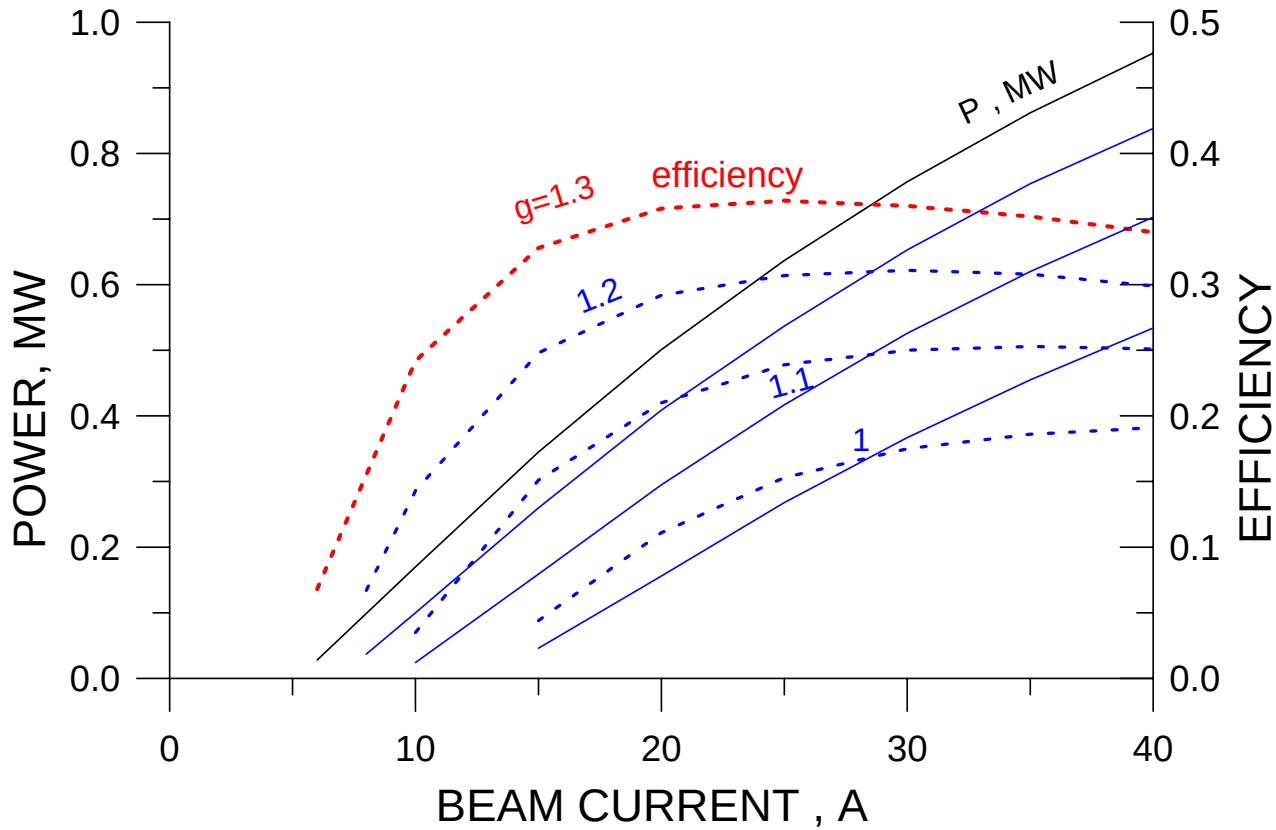
5GHz/500kW/1s Gyrotron

Profile of the cavity and distribution of an electromagnetic field.



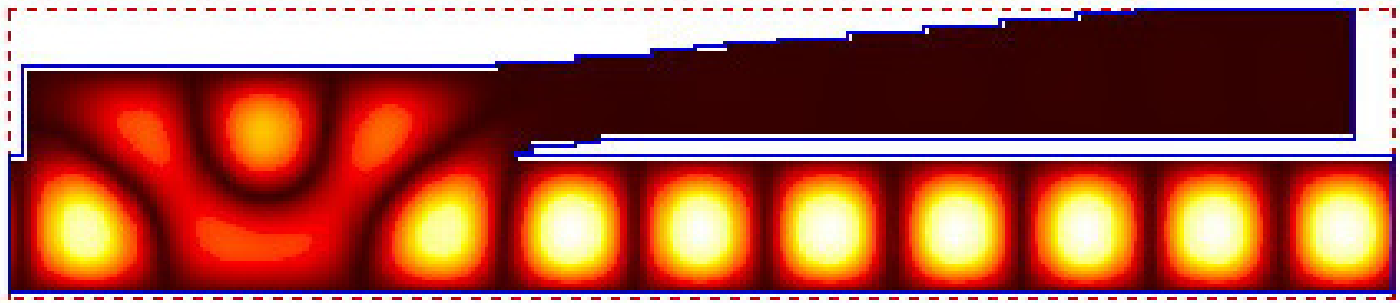
5GHz/500kW/1s Gyrotron

Calculated power and efficiency v.s beam current at various pitch-factors



5GHz/500kW/1s Gyrotron

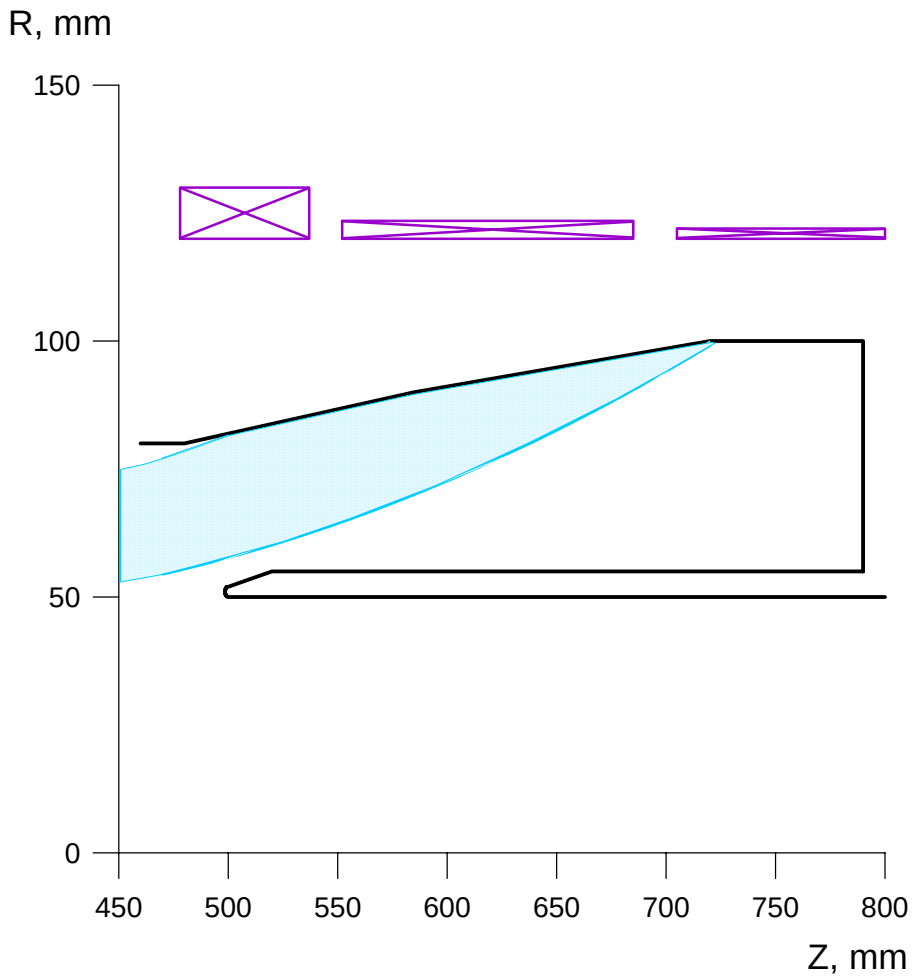
REPITER



The repeater was carried out as the shielding slot of a circular waveguide. The conic collector was interfaced to the cylindrical screen of the repeater, and the electronic beam was deduced on a collector through a ring crack between the screen and a target waveguide. Such schema of division of an electromagnetic wave and electron beam has allowed reducing considerably length of gyrotron.

5GHz/500kW/1s Gyrotron

COLLECTOR



2.5MW / 1c

5GHz/500kW/1s Gyrotron

MAGNETIC SYSTEM (Criomagnet)

Height (max)	1150 mm
Diameter (max)	650 mm
Diameter of a “warm” aperture	205 mm
Length of a “warm” aperture	760 mm
Capacity helium tank	71 liter
Capacity nitric tank	50 liters
Working current	22 A

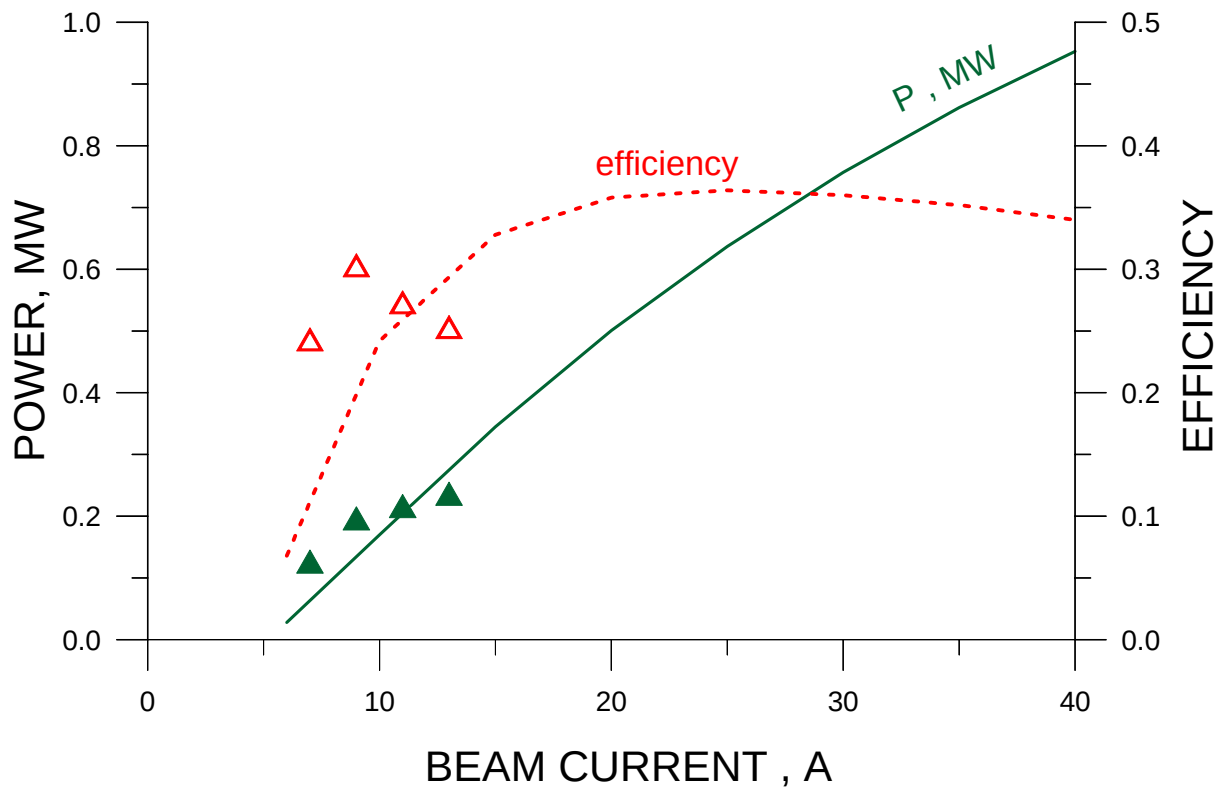
5GHz/500kW/1s Gyrotron

MAGNETIC SYSTEM (Solenoid)

External diameter	400 mm
Internal diameter	205 mm
Length	650 mm
Weight	300 kg
Power	5.5 kW
Working current	86 A

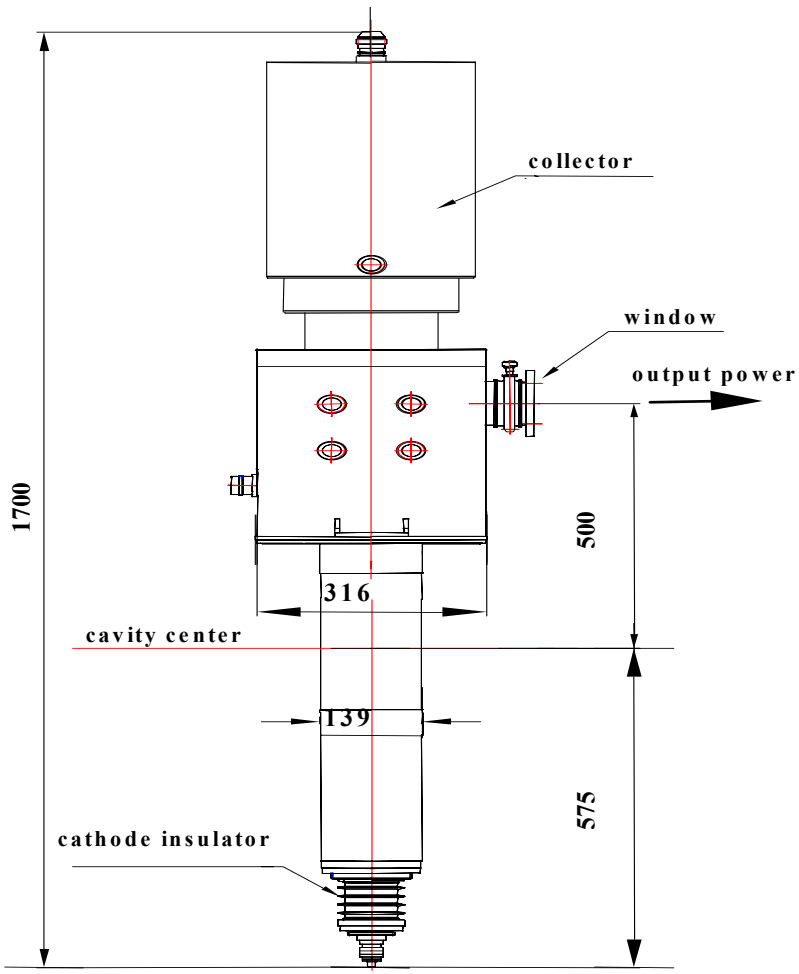
5GHz/500kW/1s Gyrotron

Calculated and measured power and efficiency v.s beam current



28GHz/500kW/0.1s Gyrotron

General view and main parameters



Operating mode	$TE_{4,2}$
Frequency	28 GHz
Electron energy	70 keV
Beam current	20 A
Pulse duration	0.1 s
Efficiency	36 %
Output power	500 kW

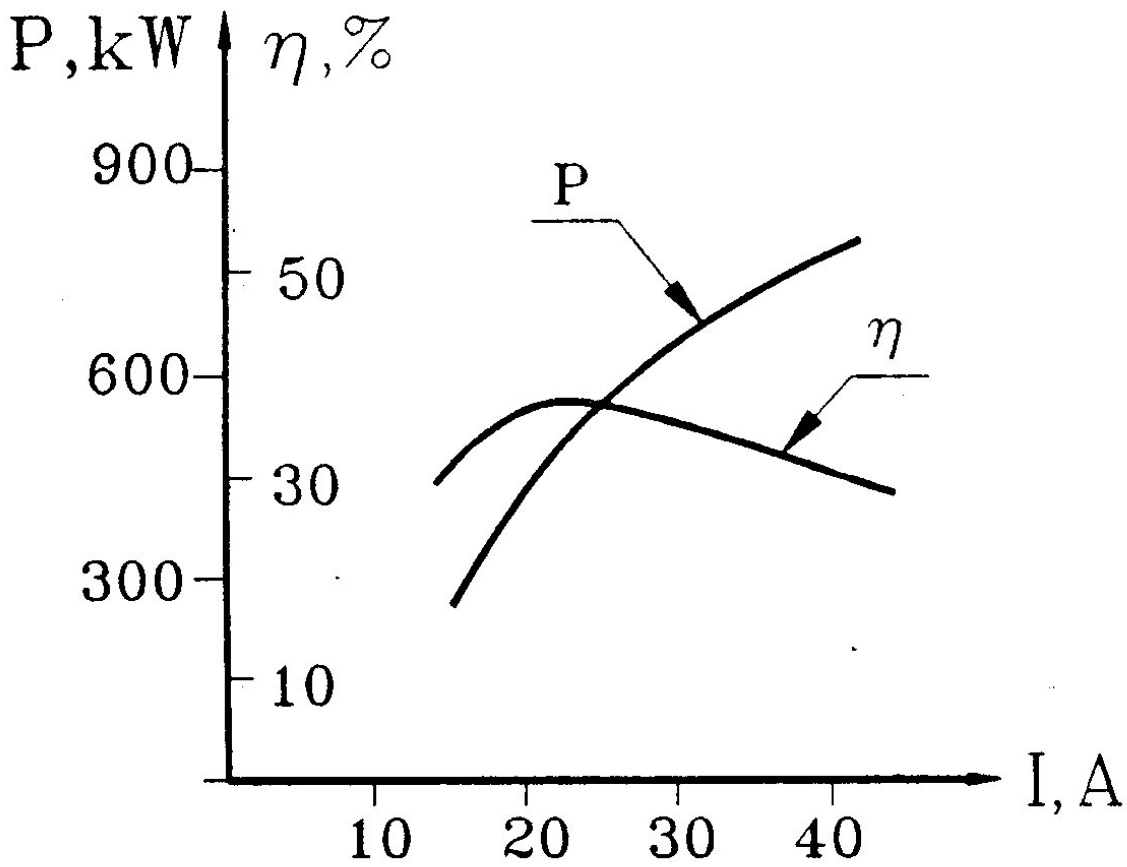
28GHz/500kW/0.1s Gyrotron

DIODE-TYPE MAGNETRON INJECTION GUN

Beam voltage	**70 kV**
Nominal beam current	**20 A**
Cathode radius	**21.5 mm**
Beam radius in cavity	**7 mm**
Density of emitter current	**2.5 A/cm^2**
Pitch-factor	**1.3**

28GHz/500kW/0.1s Gyrotron

Measured Power and Efficiency v.s Beam Current



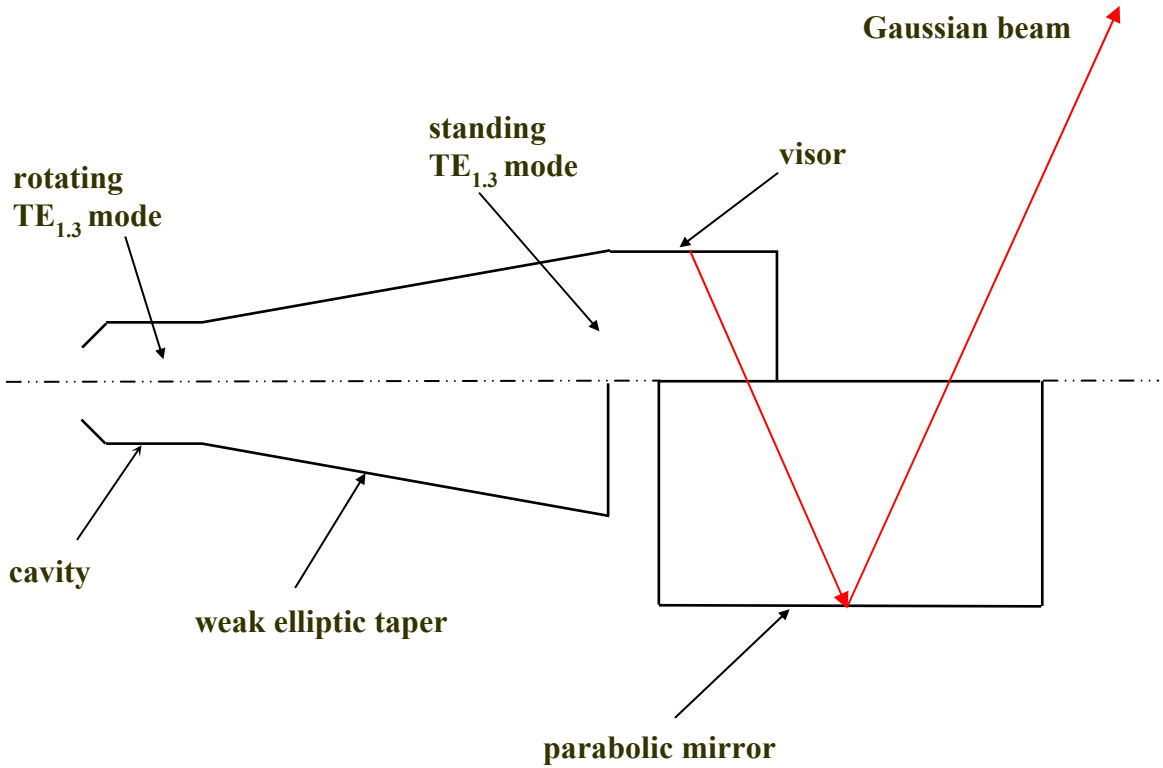
17.5GHz/1MW/5s Gyrotron Project

Design modes

mode	$TE_{4,2,1}$	$TE_{5,2,1}$	$TE_{1,3}$
ν	9.28	10.52	8.54
R_{cav}, mm	25.35	28.70	23.30
p_{ohm}, kW/cm^2	0.34	0.30	0.27

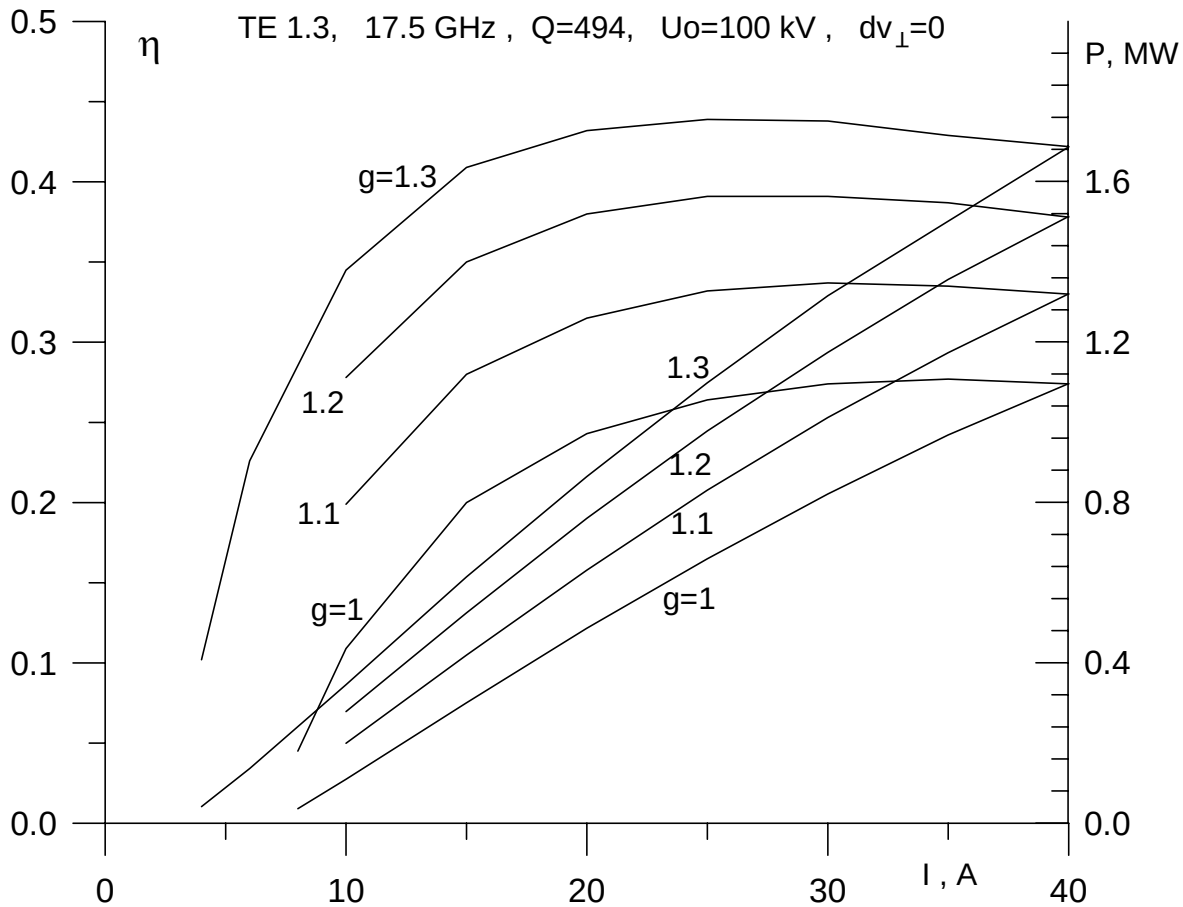
17.5GHz/1MW/5s Gyrotron Project

Mode Converter



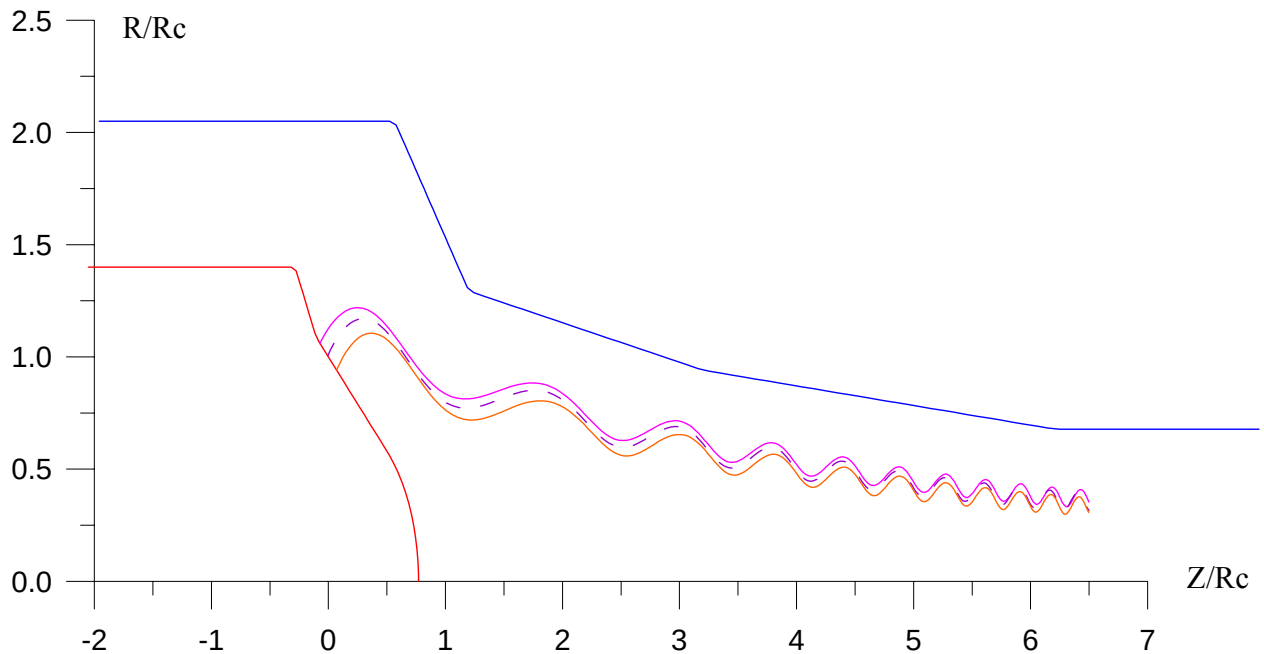
17.5GHz/1MW/5s Gyrotron Project

Gyrotron output parameters



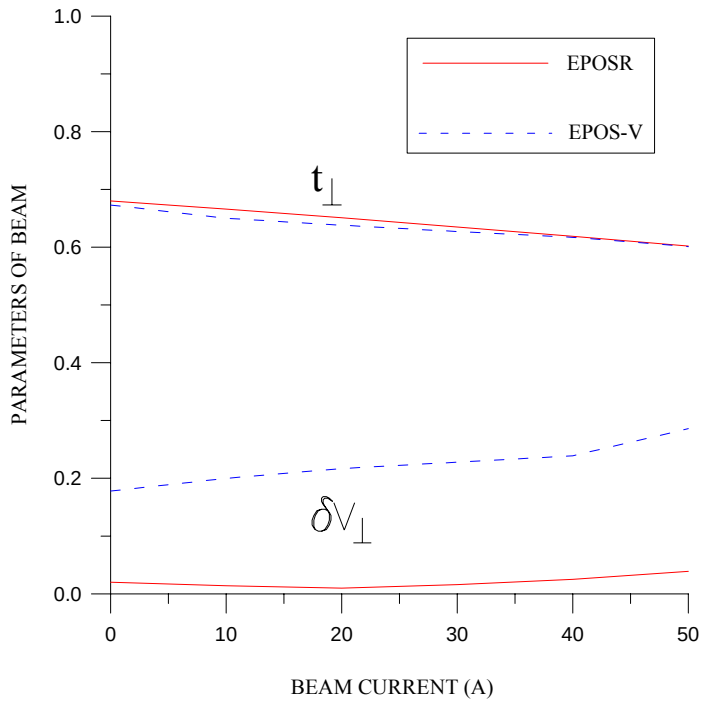
17.5GHz/1MW/5s Gyrotron Project

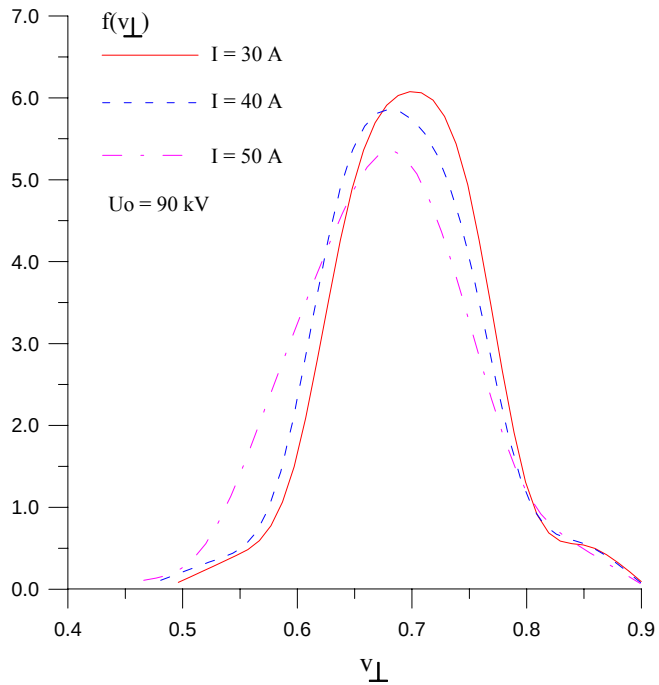
MAGNETRON INJECTION GUN



17.5GHz/1MW/5s Gyrotron Project

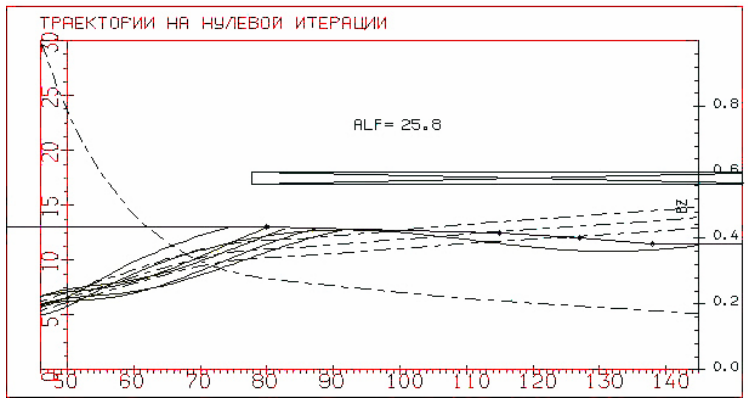
MAGNETRON INJECTION GUN



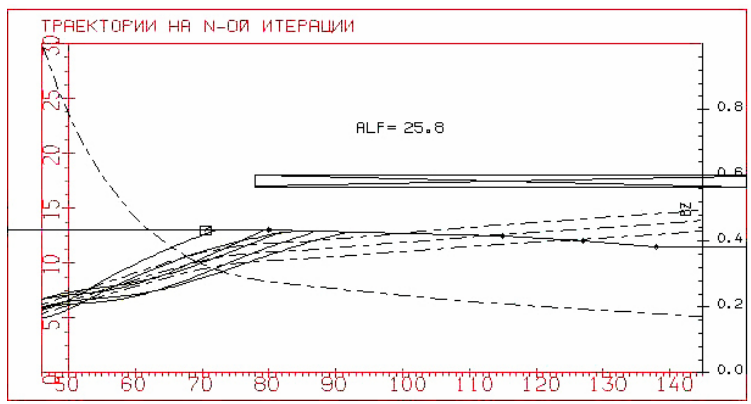


17.5GHz/1MW/5s Gyrotron Project

COLLECTOR SISTEM



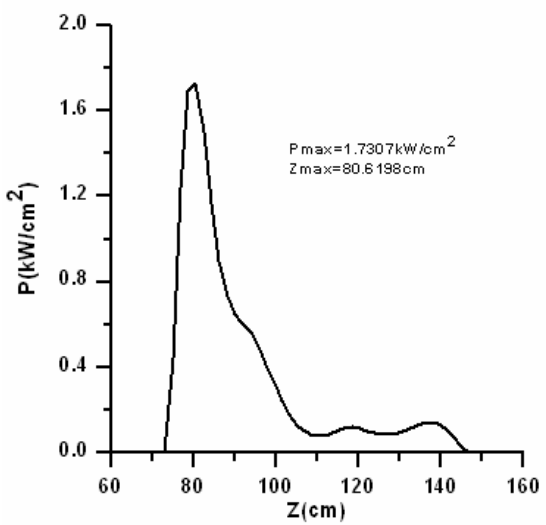
Trajectories without space charge in the system.



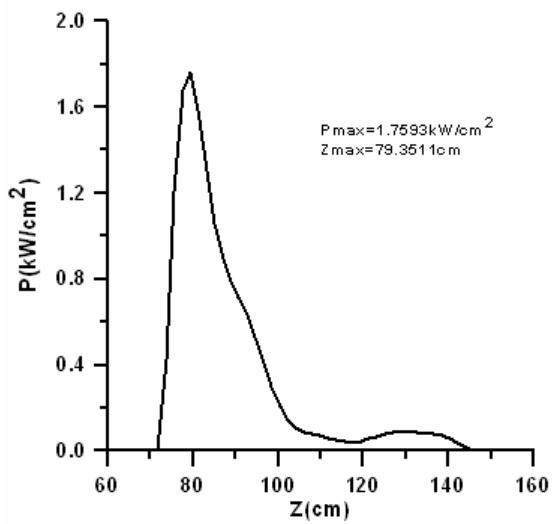
Trajectories with space charge in the system.

17.5GHz/1MW/5s Gyrotron Project

COLLECTOR SISTEM



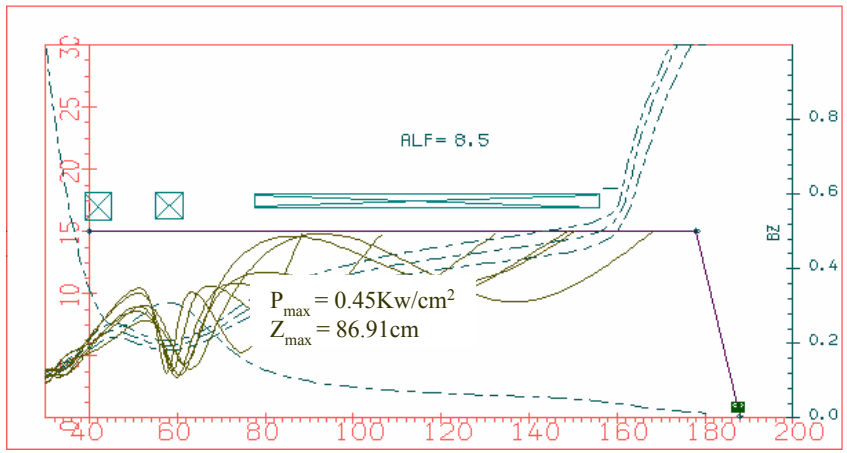
Longitudinal heat load density distribution without space charge calculation



Longitudinal heat load density distribution with space charge calculation

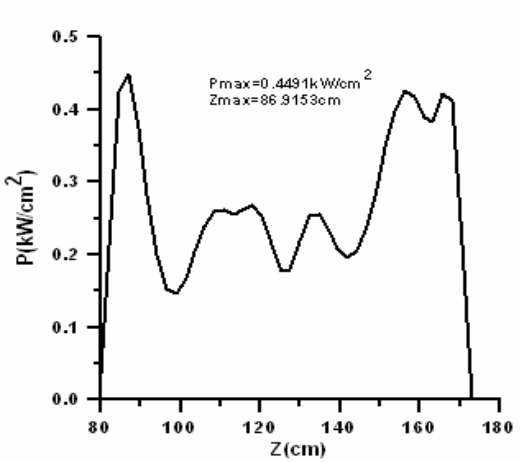
17.5GHz/1MW/5s Gyrotron Project

COLLECTOR SISTEM



Collector with 150 mm radius

Electron trajectories in optimal version.



Heat lode distribution in optimal case.

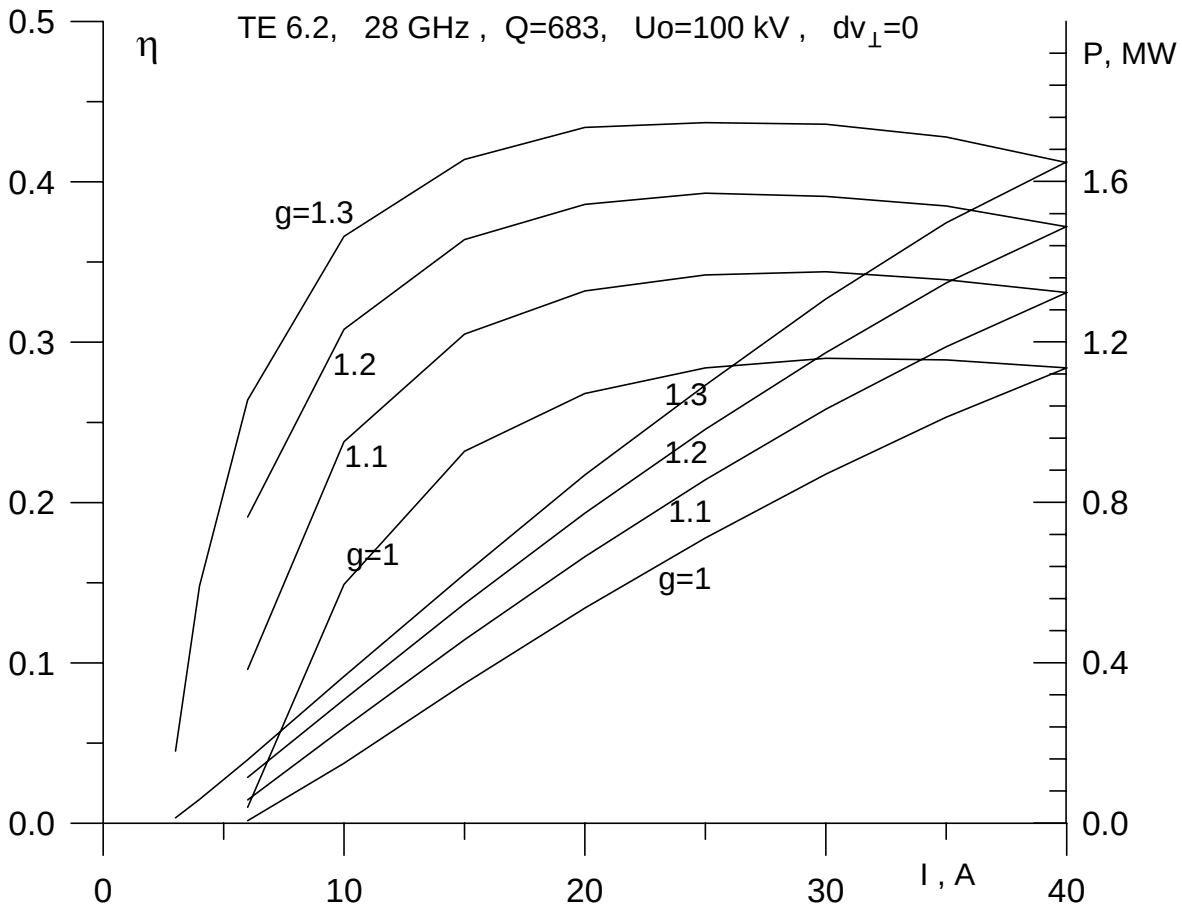
28GHz/1MW/5s Gyrotron Project

Design modes

mode	$TE_{5,2,1}$	$TE_{6,2,1}$	$TE_{7,2,1}$
ν	10.52	11.73	12.93
R_{cav}, mm	17.95	20.00	22.05
p_{ohm}, kW/cm^2	0.44	0.40	0.36

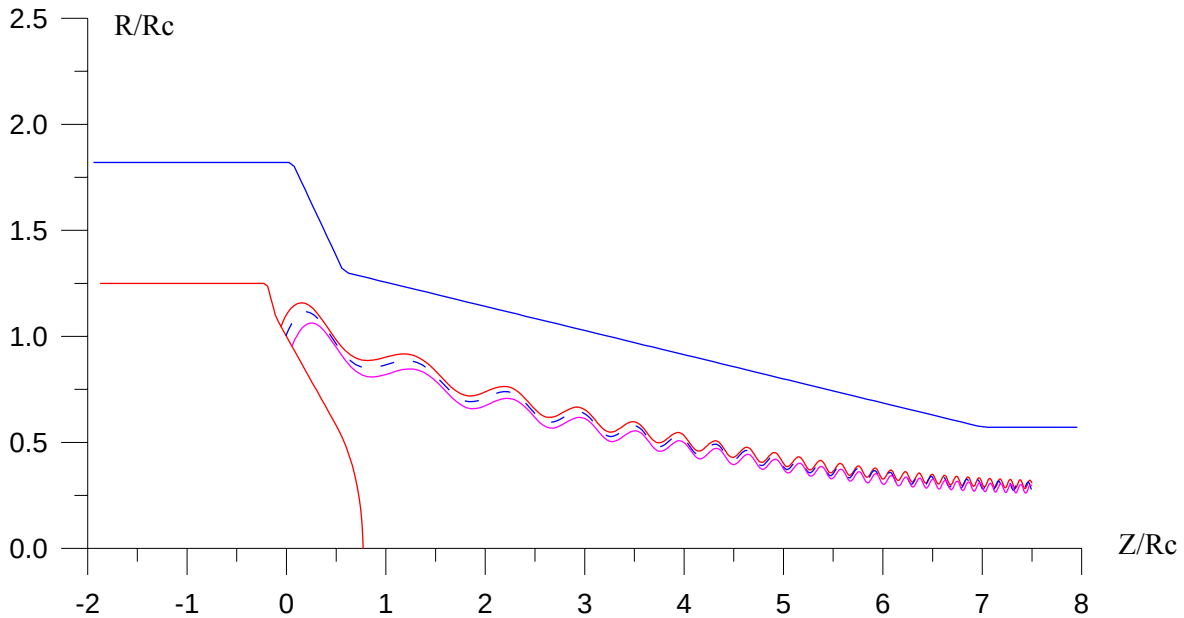
28GHz/1MW/5s Gyrotron Project

Gyrotron output parameters



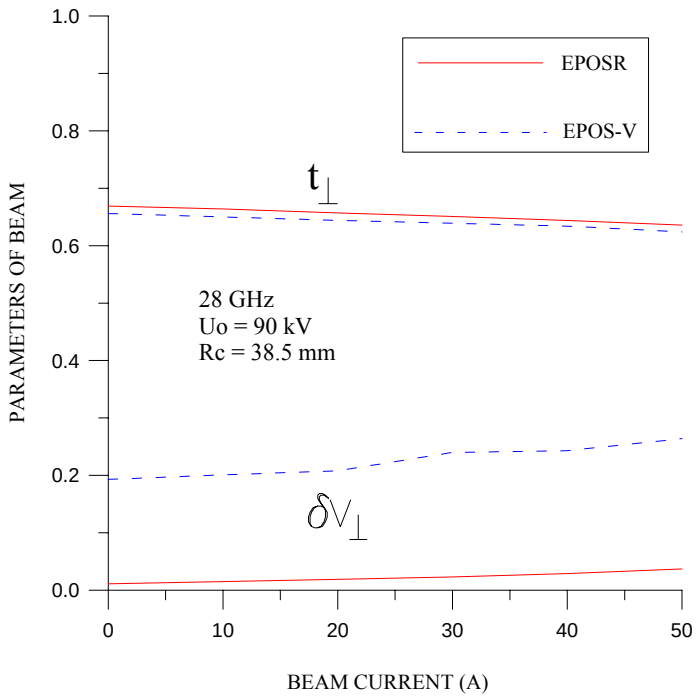
28GHz/1MW/5s Gyrotron Project

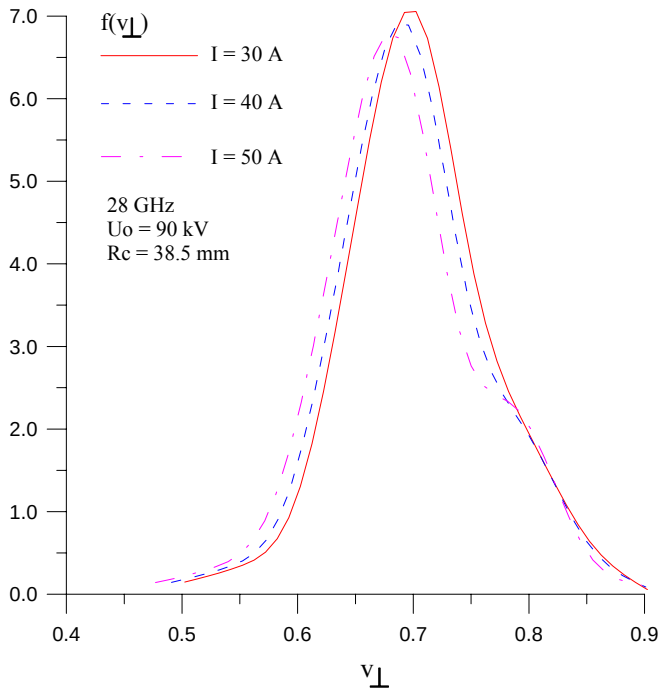
MAGNETRON INJECTION GUN



28GHz/1MW/5s Gyrotron Project

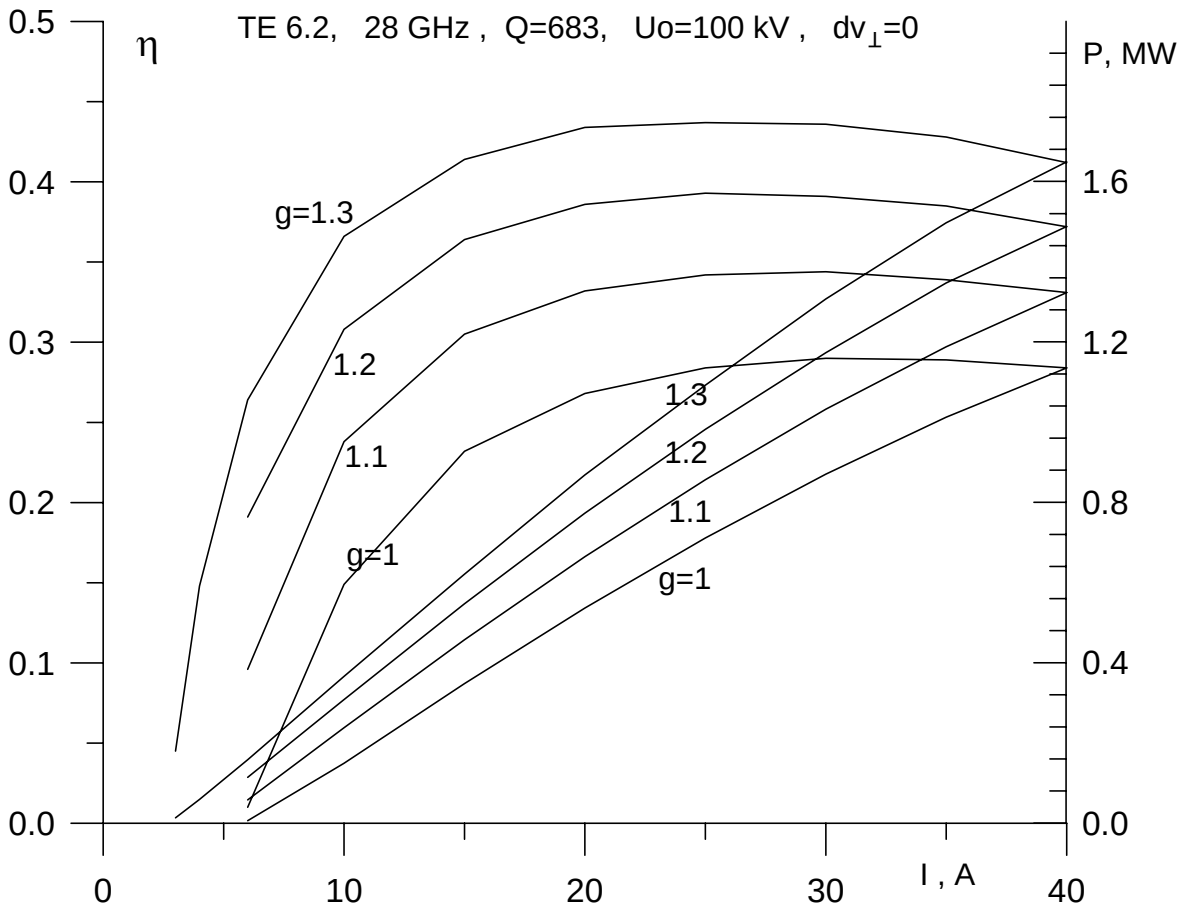
MAGNETRON INJECTION GUN





28GHz/1MW/5s Gyrotron Project

Gyrotron output parameters



Conclusion

- Low frequency powerful gyrotrons development in Russia is presented.
- The 0.5 MW/01s regime is shown at operating frequencies.
- Several design versions of 5 GHz, 17.5 GHz and 28 GHz gyrotrons with output power 0.5-1 MW, its specific property details are presented.
- Main and special technical problems of low-frequency gyrotron and test set-up are are outlined and discussed.
- The long pulse and CW versions of low-frequency gyrotron are under construction now.